Controlled Breakdown of Electromagnetic Superposition in Graphene Cavities via a Confined Longitudinal Vacuum Mode

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(Dated: December 17, 2025)

We predict a controlled and frequency-selective breakdown of the electromagnetic superposition principle in graphene cavities supporting a confined longitudinal vacuum mode (the Ψ-mode). When two coherent electromagnetic excitations are simultaneously applied at a frequency tuned to the Ψ-resonance, the resulting thermal response is not the sum of the individual responses. The deviation from additivity depends on the relative phase between the excitations and vanishes away from resonance. This behavior is incompatible with conventional optical non-linearities or thermal saturation effects and constitutes a direct, falsifiable signature of a geometrically confined vacuum-pressure channel.

INTRODUCTION

The principle of superposition is a cornerstone of linear electromagnetism: the response of a system to multiple excitations is expected to be the sum of the responses to each excitation applied independently. Deviations from superposition are normally associated with intrinsic material non-linearities, high-field effects, or electronic saturation.

Within the Quarkbase Cosmology framework, electromagnetic fields couple to matter through an underlying longitudinal vacuum-pressure field Ψ. In graphene cavities, lattice geometry confines this field into discrete cavity modes, giving rise to resonant transport and optical phenomena. In this context, electromagnetic radiation acts as a source that excites Ψ, while dissipation and thermal response are mediated by the confined vacuum mode itself.

Here we formulate a precise and falsifiable prediction: when multiple coherent electromagnetic excitations couple to the same confined Ψ-mode in a graphene cavity, the system response becomes non-additive due to the finite geometric capacity of the mode.

THEORETICAL FRAMEWORK

Consider a graphene cavity supporting a confined longitudinal vacuum mode with resonance frequency ω_Ψ. Let $R(\omega)$ denote a dissipative observable, such as temperature increase ΔT, effective thermal conductivity, or absorbed power.

For a single excitation E_i at frequency ω, the response is

$$R_i(\omega) = R(E_i; \omega). \tag{1}$$

Classical electromagnetic superposition predicts

$$R(E_1 + E_2; \omega) = R_1(\omega) + R_2(\omega). \tag{2}$$

In the Quarkbase framework, near the Ψ-resonance the response is mediated by the vacuum mode energy $\mathcal{E}_\Psi$, which has a finite modal capacity determined by cavity geometry. As a result,

$$R(E_1 + E_2; \omega_\Psi) < R_1(\omega_\Psi) + R_2(\omega_\Psi). \tag{3}$$

Crucially, for two coherent excitations at the same frequency $\omega \simeq \omega_\Psi$ with controlled relative phase $\Delta\phi$, the response becomes phase dependent:

$$R(\Delta\phi; \omega_\Psi) \neq \text{const.} \tag{4}$$

EXPERIMENTAL PROPOSAL

The prediction can be tested using standard optical or THz instrumentation without invoking high-field or non-linear regimes.

The minimal experimental configuration consists of a graphene cavity known to support a confined Ψ-mode, illuminated by a coherent electromagnetic source split into two arms and recombined at the sample with independently controlled phase.

The total incident power is kept fixed while the relative phase $\Delta\phi$ between the two excitations is varied. A dissipative observable R, such as local temperature rise ΔT, absorbed power, or an effective thermal response inferred from thermometry or thermovoltage, is monitored.

The protocol proceeds as follows: (i) measure the response to each arm independently, (ii) apply both excitations simultaneously at the same frequency with fixed amplitudes, (iii) sweep $\Delta\phi$ at constant total power, and (iv) repeat the measurement for frequencies detuned away from ω_Ψ.

PREDICTED RESPONSE

The prediction yields the following signatures:

(i) When two coherent electromagnetic excitations are applied at $\omega \simeq \omega_\Psi$, the measured response is non-additive. (ii) The deviation from additivity depends explicitly on the relative phase $\Delta\phi$ between the excitations.

(iii) For fixed total incident power, $R(\Delta\phi)$ is modulated as $\Delta\phi$ is varied. (iv) The phase dependence and non-additivity disappear when the excitation frequency is detuned from ω_Ψ.

This behavior is incompatible with heating, electronic saturation, or standard optical non-linearities, which depend on total intensity but are insensitive to relative phase at fixed power.

CONCLUSION

We predict a controlled breakdown of the electromagnetic superposition principle in graphene cavities that support a confined longitudinal vacuum mode. When multiple coherent excitations couple to the same Ψ-mode, the system response becomes non-additive and acquires an explicit dependence on relative phase. The effect is frequency-selective, reversible, and absent outside the resonance window.

This prediction does not rely on strong fields, material non-linearities, or microscopic saturation effects. Instead, it follows from the finite geometric capacity of a confined vacuum-pressure mode. Observation of a phase-dependent failure of superposition would provide direct experimental evidence for vacuum-mediated transport dynamics in graphene-based systems.

A detailed theoretical derivation of the phase-dependent Ψ-response will be presented separately.

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